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TITLE: FEEDBACK STABILIZATION EXPERIMENTS USING $\ell = 2$ EQUILIBRIUM WINDINGS IN SCYLLAC

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FEEDBACK STABILIZATION EXPERIMENTS USING $\ell = 2$ EQUILIBRIUM WINDINGS IN SCYLLAC

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ABSTRACT. The confinement time in the Scyllac Sector Feedback Experiment has been extended with a pre-programmed equilibrium compensation force. This force was produced by driving a current with a flexible waveform in an additional set of $\ell = 2$ windings.

I. INTRODUCTION. Scyllac feedback experiments have been performed on a 120° sector of the 4 M-major-radius toroidal theta pinch. Plasma parameters for the present set of experiments are the same as previously reported.[1] The configuration of the initial discharge has been altered from that of [1] to eliminate the helical oscillations of the plasma column. This has been accomplished by the use of a helical discharge tube which permits the initial implosion to create the plasma column in the helical configuration which it would otherwise dynamically approach in time.[2] The $\ell = 0,1$ sector, which is shown schematically in Fig. 1, has 13 wavelengths of the equilibrium fields with a 5 position feedback sensor system which locally drives the $\ell = 2$ feedback windings to stabilize the long wavelength, m=1 instability.[3] An additional programmable force system using an additional set of $\ell = 2$ windings is incorporated to allow for optimization of the equilibrium.

II. SECTOR END EFFECTS. Since the plasma behavior in the end regions of the sector is characterized by large displacements and accelerations, confinement time limitation due to the propagation of m=1 waves from the end regions to the center of the system has been investigated.[4] The calculated trajectory of the plasma column has been compared to the measured change in column trajectory at several positions along the sector when a step function force is applied to wavelength 10. The measured and calculated trajectory at the location of position detector No. 3 are shown in Fig. 2, and illustrate that the propagation of gross-column motion disturbances is at approximately the Alfvén velocity in agreement with the sharp boundary theory.

III. EQUILIBRIUM STUDIES. Analysis of column trajectories in the plane of the torus has indicated the need for a time-programmed force, in addition to the feedback force, to counteract an equilibrium force imbalance. Factors which influence the observed equilibrium force imbalance are (a) transients in the toroidal equilibrium force, $F_{1,0}$ due to $\ell = 0$ shape oscillations of the plasma column,[5] (b) the diffuse radial profile of the experiment which reduces the $F_{1,0}$ force from the sharp boundary design value, [6] (c) sector end effects propagating into the center of the system, and (d) decreases of β due to, for example, loss of particles from radial diffusion which, for the T_e = 100-eV Scyllac plasma, can cause a 10% drop in β in 11 μs based on classical effects alone.

The programmed equilibrium compensation force is generated with a Weibel-Jones-type circuit driving $\ell = 2$ trimming coils wound on top of the $\ell = 2$ feedback coils. Plasma trajectories and $\ell = 2$ trimming fields for two discharges are shown in Fig. 3. A small change in the amplitude of the trimming force is observed to drastically alter the trajectory. The relationship between the applied force and the observed motion can be interpreted using sharp boundary theory in terms of an effective plasma β, which is ~ 1/2 of the β on axis determined from the plasma diamagnetism and luminosity profile. This can at least partly be attributed to diffuse profile effects.

IV. FEEDBACK STABILIZATION RESULTS. The feedback system for stabilization of the m=1 long wavelength has been operated with the plasma column held near its equilibrium position by the trimming system. An improvement in confinement time to 40-50 μs is shown in the streak photograph of Fig. 4, where the column is observed to remain centered in the discharge tube for many instability growth times with feedback stabilization applied. The feedback system can generate forces on the order of 0.2 of the toroidal equilibrium force and has a risetime of 0.4 times the instability growth time. The feedback system is arranged in 5 independent arrays along the length of the 13 wavelength, 120° sector for each of the orthogonal transverse coordinates.

V. ℓ = 1,2 CONFIGURATION. The Scyllac feedback sector has been converted to an ℓ = 1,2 equilibrium configuration to eliminate transient effects on the toroidal force balance due to the ℓ = 0 field and provide a less β-dependent equilibrium. The helical shape of the plasma column has been increased to a helical radius of ~ 3.0 cm to minimize the growth rate of the m=1 instability and increase the effectiveness of the feedback stabilization. The sector has been lengthened by 40% to an arc length of 168° to increase the time before end effects influence the plasma behavior. The feedback system for the ℓ = 1,2 sector includes the capability of driving each wavelength with an individual signal which represents the sum of the required feedback forces at that location for all unstable modes.

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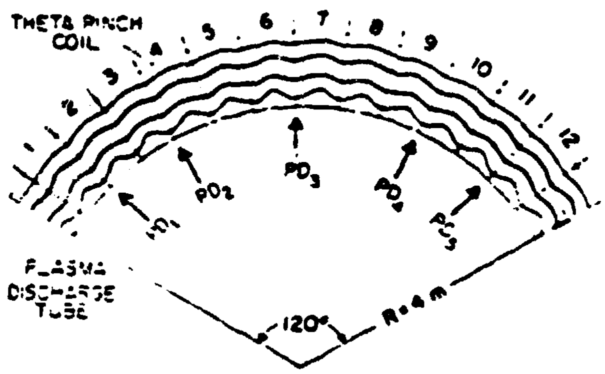

FIGURE 1 – LAYOUT OF THE ℓ=1.0 SCYLLAC FEEDBACK SECTOR

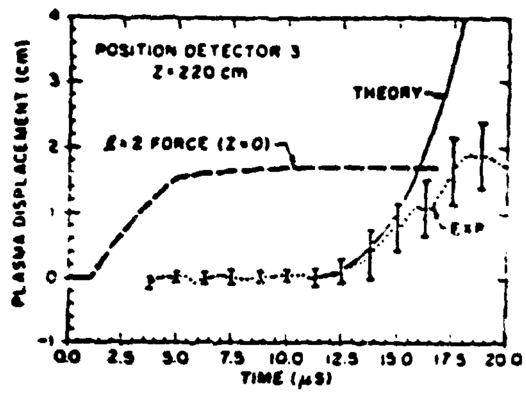

FIGURE 2 – THE PLASMA COLUMN TRAJECTORY CHANGE DUE TO A STEP FUNCTION ℓ=2 FORCE APPLIED 220cm FROM THE DETECTOR

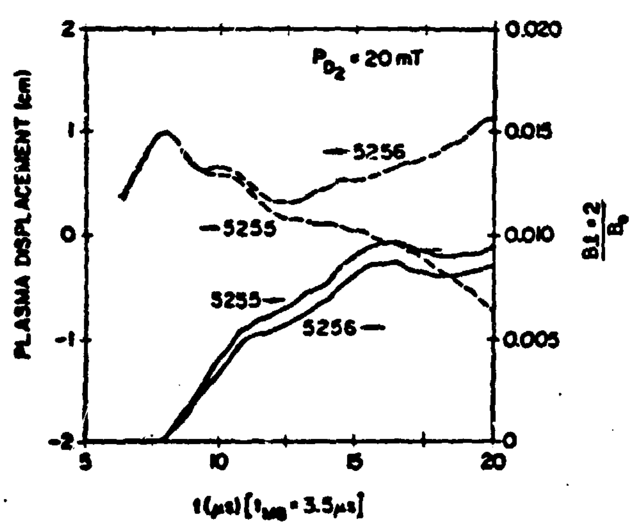

FIGURE 3 – PLASMA DISPLACEMENT VERSES TIME FOR TWO DIFFERENT AMPLITUDES FOR THE ℓ=2 EQUILIBRIUM CORRECTION FIELD

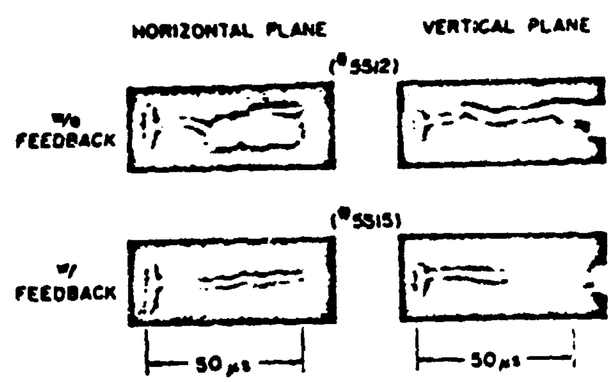

FIGURE 4 – STREAK PHOTOGRAPHS WITH AND WITHOUT ℓ=2 FEEDBACK STABILIZATION